PB-227 937

CONTROL OF AIR POLLUTION FROM THE BURNING OF INSULATED COPPER WIRE

E. R. Kaiser, et al

New York University
University Heights, New York

April 1962

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

Air pollution - wire burning AP7.4-10

PB 227 937

050187

NEW YORK UNIVERSITY

College of Engineering

RESEARCH DIVISION

University Heights, New York 53, N. Y.

AP-13

RTGB-DAP
RECEIVED
MAY 14 1962
A.M. 7 8 9 10 11 12 1 2 3 4 5 6 P.M.

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

TECHNICAL REPORT 764.3

Public Health Service
Environmental Health
Reference Room

Control of Air Pollution from the Burning of Insulated Copper Wire

E. R. Kaiser and J. Tolciss

Presented at Annual Meeting of Air Pollution Control Association

Chicago, Illinois

May 23, 1962

Supported by Research Grant from

National Institutes of Health, U.S. Public Health Service

RG-6760(C2)

27

TECHNICAL REPORT 764.3

CONTROL OF AIR POLLUTION FROM THE BURNING OF INSULATED COPPER WIRE

By E. R. Kaiser
and J. Tolciss

NEW YORK UNIVERSITY
COLLEGE OF ENGINEERING

Department of Chemical Engineering

April 1962

ABSTRACT

Insulated copper wire is burned in tonnage lots by local scrap-metal yards and copper refineries to recover the copper. The organic insulations burned include rubber, polyvinyl chloride, neoprene, polyethylene and other plastics, as well as paper fabric, and lacquers. Compounded with these plastics are metallo-organic pigments, fillers, plasticizers, and fire retardents.

Depending on the method of burning, the emissions to the atmosphere may include black smoke, chloride fumes, and ash dusts among other pollutants.

The paper describes a type of furnace that prevents carbonaceous smoke, and reports on the chloride emissions and how they can be reduced by a wet scrubber.

TABLE OF CONTENTS

	Page
ABSTRACT	
INTRODUCTION	1
Source of Air Pollution	2
State of Wire-Burner Art	3
PURPOSE OF PROJECT	4
FURNACE, AFTERBURNER and WIRE	4
GAS SCRUBBER and SAMPLING TRAIN	7
TEST PROCEDURES	10
ANALYTICAL PROCEDURES	11
RESULTS OF TESTS	12
Wire Yields and Production Rates	12
Combustion	13
Smoke	14
Gas Scrubber	14
Total Furnace Emissions	16
Neutralization and Filtration of Scrubber Water	17
DISCUSSION OF RESULTS	18
SUMMARY AND RECOMMENDATION	20
ACKNOWLEDGMENTS	21
REFERENCES	22

LIST OF TABLES

			Page
Table	I.	Wire and Production Data	13
	II.	Oil Consumption and Combustion Data	13
	III.	Smoke Shade of Unscrubbed Flue Gas	14
	IV.	Scrubber Conditions	15
	V.	Solids in Scrubber Exhaust Gas	15
	VI.	Scrubber Performance and Collection Efficiency .	16
	VII.	Metals in Suspended Flue Dust	16
	VIII.	Air Pollutants in Flue Gas and Scrubber Water .	17
	IX.	Neutralization of Scrubber Water	18

LIST OF FIGURES

Figure	1.	Wire-burning Furnace.	5
	2.	Section Through Furnace Showing Path of Gases .	6
	3.	Pilot Gas Scrubber. Overall height, 8 ft. . . .	8
	4.	Diagram of Gas-Cleaning and Sampling Train . . .	9

CONTROL OF AIR POLLUTION FROM THE BURNING OF INSULATED COPPER WIRE*

By E. R. Kaiser** and J. Tolciss***

INTRODUCTION

The recovery of copper from scrap insulated wire is practiced by many salvage yards and metal refiners throughout the country. The total copper thus annually recovered is estimated to be at least 100,000 tons from approximately 200,000 tons of insulated wire.

The wire is received by numerous small scrap yards and secondary refiners in the form of coils, bales and tangled heaps, including single and multiple strands and cables. The lead-covered cables are usually cut into manageable lengths for the removal of the lead by slitting machines. The insulation is then burned off, frequently in the open, but otherwise in furnaces. The resultant copper wire is freed of ash by shaking. The wire is compressed into bales for shipment to smelters. The ash is copper bearing and also has salvage value.

* This investigation was supported by a research grant RG 6760(C2) from the National Institutes of Health, Public Health Service.

** Senior Research Scientist, College of Engineering, New York University New York 53, N. Y. Chemical Engineering Dept.

*** Associate Research Scientist, same.

Experiments have been conducted by others to separate insulation from scrap wire by means other than burning. The methods include mechanical stripping through dies and knives, embrittlement of plastic by deep freezing, shredding, chopping, rolling, by melting with superheated steam, and by insulation solvents(1)*. Three potential advantages of such methods would be the production of cleaner copper for melting, limited salvage value of the plastics, and prevention of air pollution. The authors have learned of no commercial success of such processes but some are still promising.

The cost of processing the wire must be below 1.0 cent a pound to be commercially attractive.

A similar situation prevails in the recovery of metal values, such as silver and copper, from film, sheet and molded plastics. Photographic film is burned for silver recovery. Printed circuits on thin plastic sheets, laminations of plastic and metals, or metal inserts in plastics are readily recovered after combustion.

Source of Air Pollution

The burning of the insulation causes air pollution consisting mainly of carbonaceous particles from incomplete combustion, metal chlorides, sulfur compounds and ash dust dispersed in the combustion gases and excess air. Further investigation may well reveal other air contaminants, such as nitrogen dioxide, fluorides, hydrochloric acid vapor, and others. The flue gas and the fumes from the hot burned wire have a strong odor and attack the eyes, nose and throat.

Open burning of wire produces black smoke, but closed burning under favorable conditions will produce only a white plume caused by the chloride fumes. The white fume is undoubtedly present in the black smoke but is masked by the black particles. Of course, shades of gray result from intermediate combustion conditions.

The plastics in the insulation, such as polyvinyl chloride (PVC) and polyvinylidene chloride, neoprene, and others, contain chlorine. For example, vinyl chloride (CH_2: CHCl) is 56.8 per cent chlorine, or 58.5 per cent hydrochloric acid (HCl). Polyvinylidene chloride contains 73.2 per cent Cl and neoprene 40.1 per cent Cl, in both cases with hydrogen and carbon.

* Numbers in parentheses refer to references at end of report.

In addition to the plastic bases, various mineral and organo-mineral materials are present, serving as fillers, plasticizers, pigments, stabilizers and fire-retardent agents. Collectively, these are reported to contain among others, aluminum, antimony, bismuth, chromium, lead, magnesium, mercury, selenium, tellurium, tin, titanium, and zinc (2).

While the basic plastic polymers burn with evolution of HCl and carbon dioxide (3), the reaction of the HCl with aluminum, antimony, titanium, and zinc, for example, produces a highly volatile chloride fume (2). Some of the chlorine undoubtedly attacks the copper wire and part of the chloride remains fixed as copper chloride. Another source of white smoke is silicone rubber, which burns with release of SiO_2. Fluorocarbon-resin insulation is also destroyed by fire, releasing toxic compounds containing fluorine (4).

For completeness it should be mentioned that not all plastic bases used in insulations are halogenated. Cotton fabric, lacquers, fiber glass, and asbestos are also present but probably do not contribute significantly to air pollution.

State of Wire-Burner Art

In a limited number of cases closed batch-type furnaces have been built to burn the insulation off the wire without black or gray smoke. To prevent overheating, sintering or oxidizing the wire, the temperatures in the primary chambers are kept too low to fully consume the volatilized hydrocarbons. The latter are burned as the furnace gases flow through afterburner chambers fired by auxiliary fuel.

For example, the Cincinnati Gas and Electric Company demonstrated its incinerator to the APCA convention in 1960. Close to 1500F was maintained in a gas-fired afterburner to consume the smoke that escaped from the primary combustion chamber.

The PBM furnace of the McMahon Iron and Metals Company, Borough of the Bronx, New York City, burns wire in a batch-type primary chamber. The smoke is consumed in an oil-fired afterburner.

The Franklin Smelting and Refining Company, Philadelphia, Pa., operates a number of portable steel hoods with gas-fired afterburners which are placed by crane over piles of wire burning on the ground. (5)

The Nassau Smelting and Refining Company, Staten Island, N. Y., operates a wire-burning furnace from which the gases pass through a scrubber.

PURPOSE OF PROJECT

A series of tests of a batch-type wire burner in commercial use was undertaken by New York University

1) to obtain quantitative data on the magnitude of the air pollution from the burning of wire insulation under favorable combustion conditions,
2) to test the principle of gas scrubbing with water to remove potential air pollutants from the combustion gas, and
3) to obtain design data for use by others in planning wire burners that would cause only minimum air pollution.

It was not the purpose within the limited funds available to identify the individual air-pollutant compounds in the flue gases from wire burning, their particle sizes, and concentrations. The objective was rather to demonstrate a direct method for making a major reduction in the obvious air pollution from the wire-burning process.

FURNACE, AFTERBURNER AND WIRE

Figure 1 is an exterior view of the prototype furnace that had been described previously (6) for burning automobile bodies at the Michael Schiavone & Sons, Inc., New Haven, Conn. It had also been used successfully for some months in burning insulated copper wire.

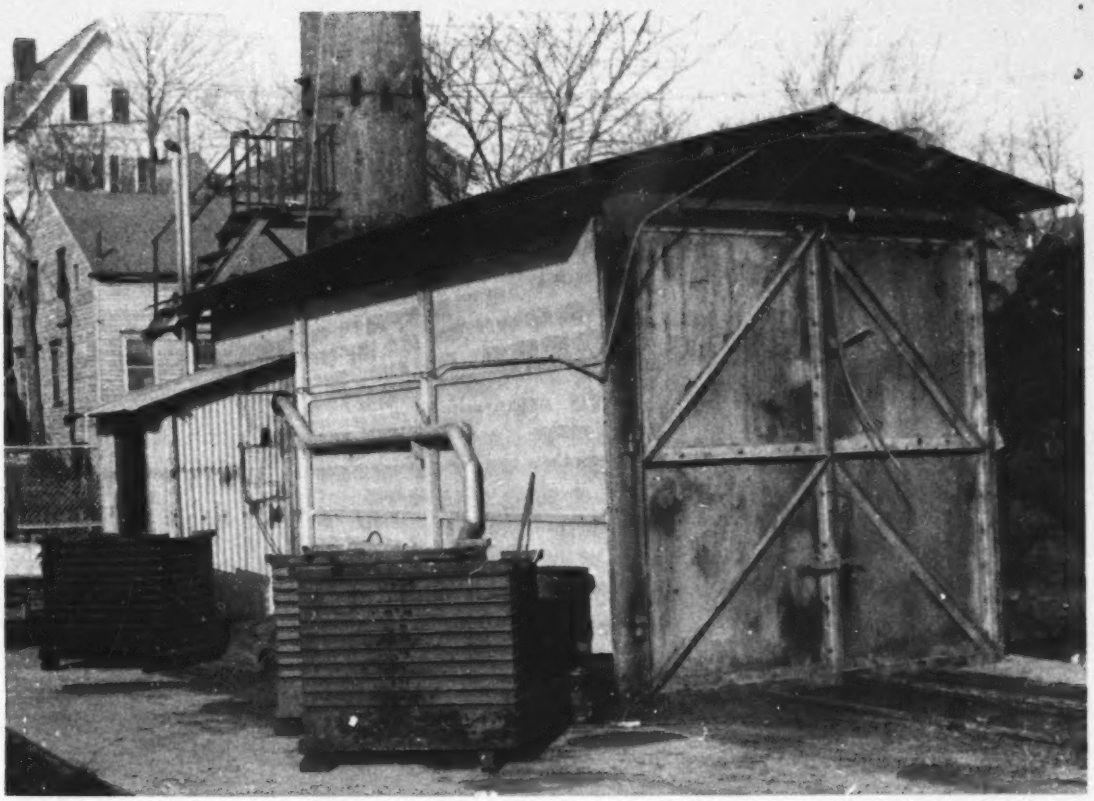

Figure 1. Wire-burning Furnace.

Figure 2 is a diagrammatic section to show the arrangement of the primary chamber, wire layer, afterburner and stack.

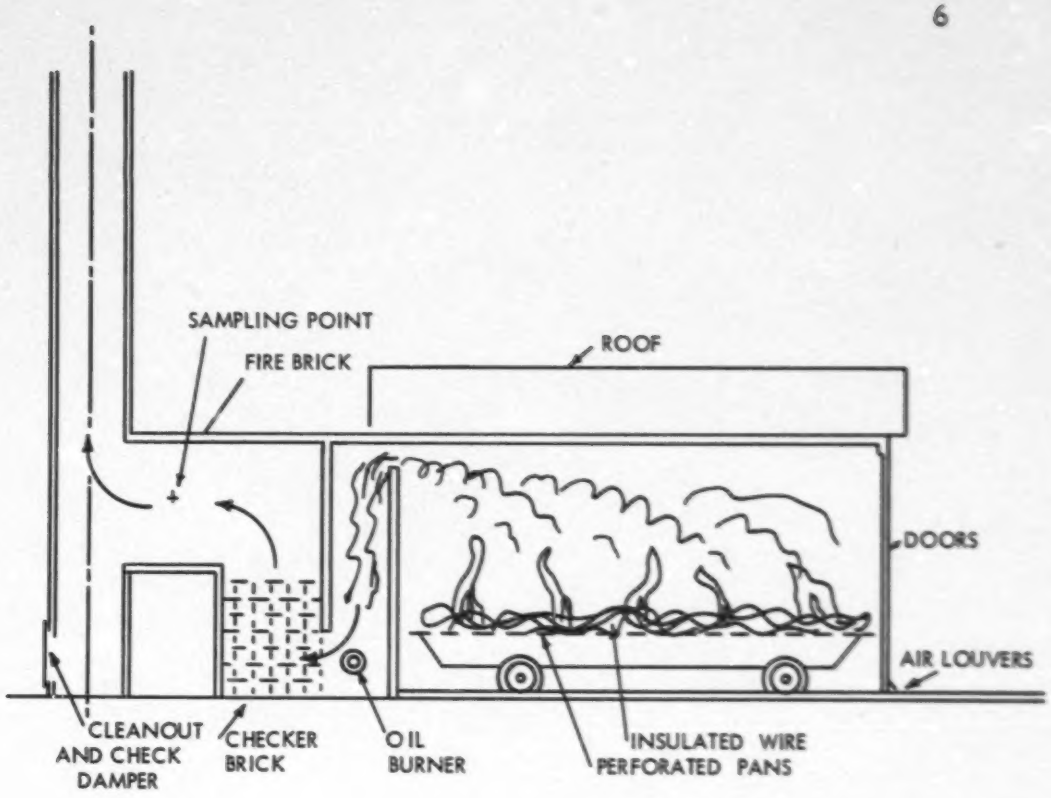

Figure 2. Section Through Furnace Showing Path of Gases.

The interior plan area of the firebrick-lined primary chamber was 9.5 x 19.5 ft, or 185 sq ft. The firebrick afterburner chamber at the rear of the furnace was equipped with a single oil burner of 4-36 gph capacity operating on No. 4 fuel oil. The checker chamber following the oil burner contained 250 firebricks weighing 2000 lb. Its purpose was to store heat for assisting combustion and to promote combustion-gas turbulence.

The wire was spread on two perforated steel pans, 8x7.5 ft or 60 sq ft each, which were moved into and out of the primary furnace on a winch-operated steel cart. The pans were lifted by a fork-lift truck.

A wide variety of insulated copper and copper-clad wires was burned, with insulations ranging from about 10 to 80 per cent of the weight of individual wires. The sources included industry, telephone companies, demolition projects, and old motors. Motor and coil windings seldom had sufficient insulation to sustain combustion in a cold furnace and were therefore mixed with wire of higher insulation content. Some of the wire had been in use many years, but much of it was relatively new. Seldom was any of the wire over 12 gage.

GAS SCRUBBER AND SAMPLING TRAIN

Despite nearly complete combustion, the gases leaving the afterburner contained particulate matter, mostly fumes, which should be removed before the gases are discharged. To clean the products of combustion from wire burning before discharging to the atmosphere requires equipment which can handle gases at up to 1800F and can remove fine fumes, acid vapors, and chlorides. Wet collectors or scrubbers appeared to be most promising for the purpose, and offered hope of trapping low-boiling chlorides.

A small pilot-scale Peabody gas scrubber of stainless-steel construction was installed beside the furnace breeching to clean a representative stream of flue gas leaving the afterburner during each entire test burn. The scrubber had a diameter of 6 inches and a nominal capacity of about 120 lb of flue gas per hr.

As shown in Figure 3, the scrubber column was equipped with a sump, recirculating water pumps, manometers, flow meter, pressure gages and thermometer. The flow of gas through the scrubber was produced by an exhauster fan with bleed valve for control.

The flue gas was drawn from the center of the breeching through a funnel-shaped nozzle facing upstream. The nozzle diameter was varied from 2.8 to 3.3 inches to closely approximate isokinetic sampling by the scrubber.

The complete assembly of scrubber and gas sampling train is shown schematically in Figure 4.

On their way to the scrubber the gases were first cooled by a water spray (A) in the duct between the breeching and scrubber. The unevaporated water drained into the scrubber. The water-saturated gases were again sprayed with water (B) as they approached and entered the "agglomerator stage" (C) which consisted of a small orifice(s) followed by a layer of water and a mixing tube(s), all designed to promote intimate contact of water and gases in a highly turbulent condition.

The gases and entrained water next flowed upward through an "impingement deck" (D) consisting of 3/16-inch holes covered with baffles in a layer of water. This stage was less turbulent, permitting the entrained solids and water to separate from the gases. Unevaporated water and wet solids were given further opportunity to separate from the gases in the baffle section near the top of the scrubber.

While the scrubber drained constantly into the sump, the pumps recirculated scrubber water to the spray nozzles and impingement deck. Two pumps were used as a convenience for the tests; one pump is normally used on full-scale scrubbers.

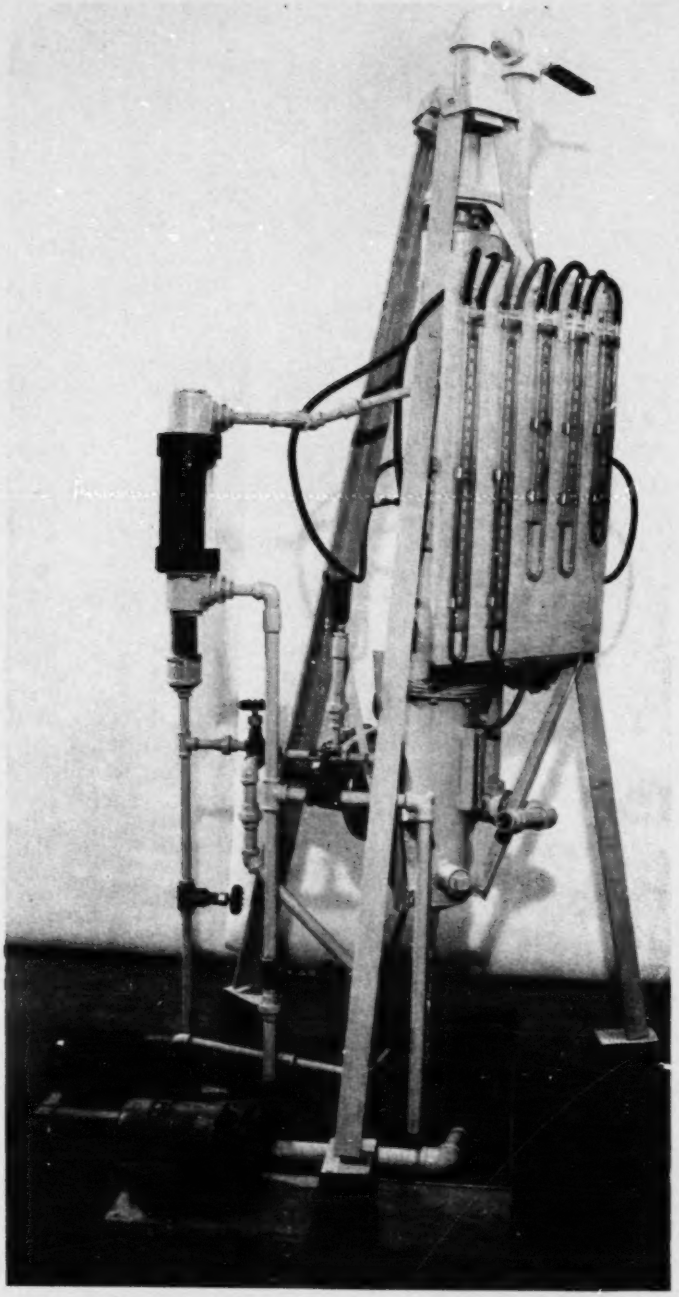

Figure 3. Pilot Gas Scrubber. Overall height, 8 ft.

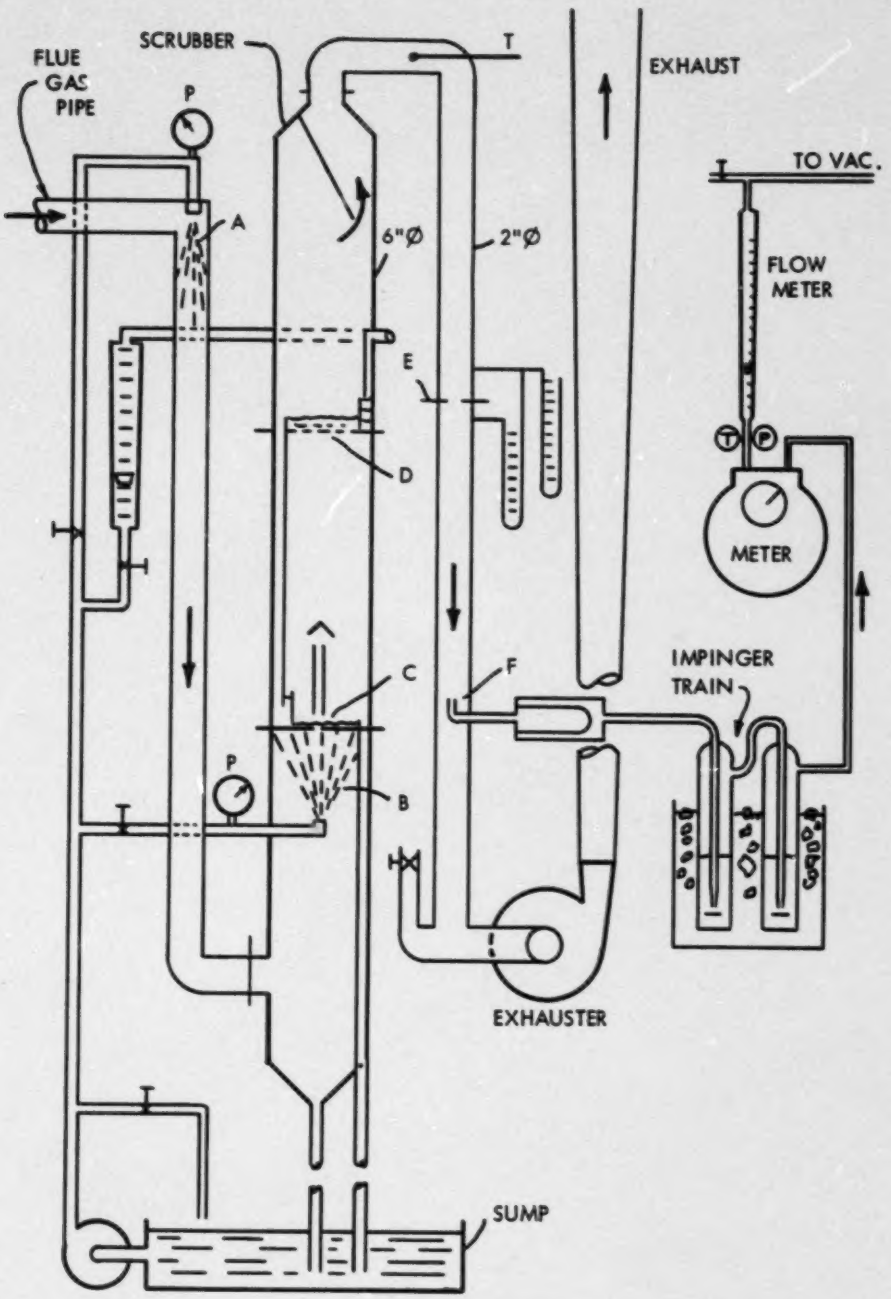

Figure 4. Diagram of Gas-Cleaning and Sampling Train.

The saturated gases leaving the scrubber passed through a square-edged orifice meter (E) on their way to the exhauster. The gas was sampled isokinetically (F), and passed successively through heated Whatman filter thimbles, chilled wet and dry impingers, gas meter, flow meter and vacuum pump. The particulate matter not trapped by the scrubber was caught by the filters and impingers. The impingers were in an ice-water bath to condense water and HCl (if any), as well as to trap aerosols that passed through the filter thimbles.

No provision was made to sample the breeching gas or the scrubber inlet gas, as it had been found from previous experience (7) that greater accuracy would result by considering the total pollutants as the sum of the scrubber catch and the pollutants escaping in the scrubber exhaust, the latter determined by means of the sampling train.

TEST PROCEDURES

Three preliminary tests were conducted to measure combustion conditions, gas flow rates and the general nature of the air pollutants.

Three test burns were then made under each of three sets of scrubber conditions to determine how much improvement in scrubber efficiency would result from increasing the pressure drop through the scrubber. The area of agglomerator orifices and the gas mass flow rates were changed for each series of tests, as will be explained later.

Weighed lots of insulated wire were spread across the pans, more or less evenly, to a depth of 8 to 10 inches. A greater depth was found to cause excessive temperatures in the layer, resulting in burning and clinkering of the copper.

The charge was sprinkled with No. 2 fuel oil to promote ignition, as the insulation was compounded to be fire resistant. In the meantime the afterburner had been brought to 1200 to 1400F breeching temperature by oil firing. The charge was then ignited with oily rags, the doors closed, and the scrubber exhaust fan started. The scrubber flow rate were established in a few seconds, following which the gas sampler was promptly adjusted to the predetermined rate. The air admission ports of the furnace were left fixed in the same partly open position throughout each burn.

The breeching temperature started to rise as ignition spread through the wire. The heat release of the oil burner was reduced to maintain approximately 1500F at the breeching. The wire was left in the furnace until all flames had subsided and the wire had practically stopped emitting fumes. The latter stage consumed at least one third of the total time.

The top of the stack was observed frequently, especially during the first third of each burn when the ignition was spreading through the wire and gray smoke might be produced.

Because of the batch operation, the initial supply of water remained in the circuit for the entire burn except for the replacement of 2.5 gallons of scrubber water with 2.5 gallons of fresh water about mid-test. Except for this, the content of impurities in the water increased during the test.

The scrubber water was sampled before each burn but only after circulating it through the scrubber prior to the burn. The scrubber was rinsed with fresh water at the end of each burn, rinse and scrubber water were then combined, measured and sampled.

At the end of each burn, the wire was removed, ash being shaken off with forks. No. 2 grade copper wire and the copper-bearing ash were weighed separately. The sampling train was dismantled and cleaned after each burn.

ANALYTICAL PROCEDURES

Samples of the scrubber water before and after each burn, and of the impinger water, were evaporated to dryness, the residues cooled in a desiccator and weighed. The washings of the dust-sampling probe and tubing were similarly evaporated, dried and weighed. The paper thimbles were dried in an oven at 104C for 24 hours before weighing. Great care was exercised in the weighing of the thimbles as they readily reabsorbed moisture from the atmosphere.

Samples of the scrubber water were filtered through Whatman paper, washed, and evaporated to dryness to determine the amount of soluble matter. Samples of filtered scrubber water were titrated with potassium hydroxide (KOH) to determine the amount of neutralizer necessary to treat the scrubber water before it could be discharged to waste on a large scale. Lime (CaO) was used for the same purpose on some duplicate samples.

As black and dark green floc was produced on adding alkali to samples of scrubber water, this effect was investigated further. The floc was produced until the solutions were neutral to methyl red and litmus. The presence of chlorides in the scrubber was confirmed by silver nitrate.

The presence and amount of chlorides in the impinger water, which indicated chlorides in the scrubber exhaust, was determined similarly by titration with silver nitrate and KOH.

To investigate the possible presence of free HCl in the scrubber and impinger water, samples were distilled until the residues were dry, after which the distillates were titrated.

Samples of the oil and insulation were sent to a commercial laboratory for Btu determinations. A sample of particulate matter taken over the entire period of a burn was submitted for spectroscopic analysis.

RESULTS OF TESTS

Data are given only for the time between lighting the wire and reopening the furnace for removal of the wire. While the period for reloading the furnace is important in daily throughput, little or no air pollution is caused during that time.

Wire Yields and Production Rates

A total of 11,173 lb of wire was charged during the nine tests. The yield of No. 2 copper was 6000 lb or 53.5%, while the copper-bearing ash totalled 1190 lb. The weight loss by combustion, including combustibles, and air pollutants, was 3983 lb. The average weights per test are given in Table I.

Table I. Wire and Production Data, Avg. per Test

Series	A	B	C	
Test No.	16,17,18	19,20,21	22,23,24	Avg. per cent
Insulated wire charged, lb	1241	1347	1137	100.0
No. 2 copper recovered, lb	664	711	625	53.5
Cu-bearing ash, lb	123	127	147	10.8
Weight loss, by diff., lb	454	509	365	35.7
Insulated wire on pans, 120 sq ft area				Avg.
Lb per sq ft	10.3	11.2	9.5	10.3
Lb per cu ft	n.d.	14.7	15.0	14.9
Production rate in furnace				
Time for burn, minutes	78	83	80	80
Wire-burning rate, lb per hr	955	972	851	926
Same, per sq ft of pan area	8.0	8.1	7.1	7.7

Combustion

The consumption of oil sprinkled on the wire to promote ignition and that fired into the afterburner during the burns are tabulated in Table II. The heat release from the burning insulation (10,000 Btu per lb) and from the oil are also given. The lower consumption of oil in Series B was the result of a larger amount of insulation burned.

Table II. Oil Consumption and Combustion Data, Avg. per Test

Series	A	B	C	
Test No.	16,17,18	19,20,21	22,23,24	Avg.
Oil consumption during burn				
No. 4 afterburner oil, gal	35.2	31.2	35.7	
No. 2 ignition oil, gal	2.5	2.5	2.5	
Total	37.7	33.7	37.2	
Per ton of wire, gal	60.6	50.0	65.4	58.7
Heat release, Btu per burn				
From insulation	5,770,000	6,360,000	5,120,000	
From oil	5,490,000	4,850,000	5,550,000	
Total, Btu per burn	11,260,000	11,210,000	10,670,000	
Heat release, Btu per hr, avg	8,660,000	8,100,000	8,000,000	
Air supplied, lb per hr	16,800	16,500	18,200	
Excess air, % of theoretical	158	171	203	

The water of combustion produced was 1.235 lb per lb of oil and 0.94 lb per lb of insulation.

Smoke

The open burning of insulated wire produces black smoke followed by some white fume. By closed burning with an afterburner, the carbonaceous black smoke from the primary chamber can be burned to any degree desired.

The preliminary tests had shown that when the excess air exceeded 25 per cent the gray appearance due to carbon usually disappeared when the breeching gases were at 1500-1550F. Later in the burn after the hydrocarbons had burned out of the charge and the wire was cooling but continuing to fume, the breeching temperature could be allowed to decline below 1500F.

The smoke readings on the unscrubbed gases leaving the stack are summarized in Table III by percentage of the total burn time.

Table III. Smoke Shade of Unscrubbed Flue Gas

Series	A	B	C
	-- Per cent of total time of burn --		
Gray, No. 2 Ringelmann	0.9	2.0	14.2
Light gray, No. 1 Ringelmann	3.4	16.0	24.7
White	47.6	66.8	42.7
Clear	48.1	15.2	18.4
	100.0	100.0	100.0
Breeching Gas, F avg.	1521	1436	1290

A more detailed comparison of the smoke readings and the gas temperatures than given above show that the gray smoke occurred during the first quarter of the burn when the temperatures were below 1500F. Some burns ran cooler throughout than others. The general correlation of gray smoke and breeching temperatures is also evident from Table III.

As the scrubber exhaust entered the winter air it took on the appearance of a light steam fog, which disappeared by evaporation within 6 ft of the exhaust pipe without leaving a trace of smoke.

Gas Scrubber

In Test Series A the agglomerator had two nozzles each of 7/16-inch dia. through which all of the saturated scrubber gas and entrained water passed by virtue of a pressure drop of 22.4 inches, water gage (wc.). At the rate of gas flow in Series A the demister baffle at the top of the scrubber was not fully satisfactory in preventing entrainment of moisture droplets. The gas rate was therefore reduced for Series B and C, and the agglomerator orifices reduced in size for two conditions of pressure drop, as given in Table IV.

The cold scrubber water was soon heated by the scrubber gas, after which some evaporation into the gas stream occurred. The saturation temperature of the flue gas in the scrubber was lower than for a full-scale unit because of the proportionately higher heat losses from the smaller piping, sump and scrubber shell. On a full-scale unit the exhaust temperature would have approached 160F and the water consumption would have been higher per 1000 lb of flue gas.

Table IV. Scrubber Conditions, Avg. per Test

Series	A	B	C
Time of burn, minutes	78	83	80
Breeching flue gas, avg F.	1521	1436	1290
Scrubber exhaust gas, avg F.	135	112	110
Flue gas scrubbed, lb	152	123	116
Agglomerator port area, sq.in.	0.3006	0.1963	0.1503
Press. loss thru agglom., in. wc.	22.4	21.9	37.0
Impinger plate area, sq.in.	6.91	6.91	6.91
openings, area, sq in.	1.52	1.52	1.52
Press. loss thru impinger, in. wc.	3.6	2.1	2.0
Press. loss thru scrubber and piping, in. wc.	30.3	31.7	42.7
Scrubber water per burn			
Total supplied, gal.	16.3	15.8	15.8
Total recovered, gal.	13.2	14.3	14.7
Water sprays, gpm	2.0	2.0	2.0

To evaluate the scrubber performance, the particulate matter in the scrubber exhaust was determined from the quantity of gas sampled and its dust loading. The data are summarized in Table V.

Table V. Solids in Scrubber Exhaust Gas

Series	A	B	C
	-- Data per burn, averaged --		
Weight of dry gas thru meter, lb	4.20	4.09	5.16
Equivalent flue gas, lb.	4.36	4.24	5.36
Dry solids in gas, gm. In thimbles	0.4225	0.6088	0.5265
In probe washings	.2050	.3494	.2378
In impingers	.1149	.1272	.0594
Total, gm.	0.7424	1.0854	0.8237
Flue gas entering scrubber, lb	152	123	116
Solids in total scrubber exhaust, lb	0.0570	0.0694	0.0392

Aliquots of scrubber water from the beginning and end of the tests were evaporated to dryness and the residues were weighed to determine the amount of solids caught by the scrubber. The average results per burn for each series of tests are given in Table VI, below:

Table VI. Scrubber Performance and Collection Efficiency

Series	A	B	C
Solids caught by scrubber, lb	0.7514	0.8420	0.6620
Solids escaping scrubber, lb	.0570	.0694	0.0392
Total solids in flue gas, lb	0.8084	0.9114	0.7012
Scrubber collection effic. for solids, %	93.0	92.4	94.5

A spectro analysis of a sample of the particulate matter collected from the flue gas during one entire burn showed the following metals present in the ranges given:

Table VII. Metals in Suspended Flue Dust

Metals	Amount Present, %
Cu, Zn	Over 10
None	1.0 to 10
Mg, Pb, Si, Fe, Bi, Al, Ca	0.1 to 1.0
V, Sn	0.01 to 0.1

The metals were present mainly as chlorides. The presence of a high percentage of copper confirms the weight loss of copper to the flue gases experienced by others. Tin is present as a coating on some copper wire and, with lead, is a constituent of solder on the ends of some wires. The other elements originated mainly in the insulation, as explained earlier.

Total Furnace Emissions

The weights and concentrations of particulate matter in the total flue gas for the burns were calculated from the data presented in the previous tables, and summarized in Table VIII as average values per burn. Had the scrubber been operated at 94.5% efficiency, the dust emissions to the atmosphere would have been as given on the last line of the table.

Table VIII. Air Pollutants in Flue Gas and Scrubber Water

Series	A	B	C
Total flue gas per burn, avg lb	22600	23600	24900
Flue gas scrubbed, avg lb	152	123	116
Total solids in gas scrubbed, avg lb	0.8084	0.9114	0.7012
Solids in total flue gas, lb	120	175	151
Flue dust per ton of wire, lb			
In raw flue gas	193.0	260.0	266.0
In scrubbed flue gas	13.6	19.9	14.7
In scrubber water	179.4	240.1	251.3
Excess combustion air, %	158	171	203
Initial dust loading, lb per 1000 lb flue gas corr. to 50% excess air	9.12	13.4	12.3
Final dust loading of scrubbed gas, lb per 1000 lb, corr. to 50% excess air	0.638	1.02	0.675
Same with scrubber at 94.5% collection efficiency	0.501	0.735	0.675

Neutralization and Filtration of Scrubber Water

The scrubber water was acidic, but on distillation to a dry residue, virtually no acid was found in the distillate, which indicates there was little or no free hydrochloric acid in the flue gas. The acid character of the scrubber water and the slight acidity of the impinger water were caused by metal chlorides. Before the scrubber water could be discharged to streams or sewers it would be necessary to neutralize and clarify the water.

Upon adding alkali, such as KOH or lime, to the samples of final scrubber water, first a black and then a dark green floc was produced, which was removed by filtration. The floc consisted of metal hydroxides, while the solution contained neutral potassium or calcium chloride. For example,

$$CuCl_2 + CaO + H_2O \longrightarrow Cu(OH)_2 + CaCl_2.$$

Some insoluble particles were present in the final scrubber water, but 77 to 91 per cent of the solids were in solution. Upon filtration of the neutralized water a clear uncolored liquor was produced.

KOH was used as a convenience for titration in the laboratory because of its high solubility. However, lime was demonstrated to have the same effect, and would be more economical in commercial practice(8).

Table IX. Neutralization of Scrubber Water

Series	A	B	C	Avg.
KOH reqd. to neutralize final scrubber water, lb	0.341	0.636	0.414	-
Equivalent lime (CaO), lb	0.170	0.318	0.207	-
Lime reqd. per 1000 lb flue gas, lb	1.12	2.58	1.78	1.83
Lime reqd. per ton of wire, lb	40.7	90.5	78.0	69.7
$CaCl_2$ in neutralized scrubber water per ton of wire, lb	80.5	179	154	138

By combining proportionate quantities of filtered scrubber water from the nine tests, neutralizing and filtering, 3.41 gm of dry metal hydroxides were obtained from 772 ml of final scrubber water. Had all of the flue gas been scrubbed, the dry yield of metal hydroxides by flocculation and filtration would have been 151 lb per ton of wire. The initial insoluble particulate matter would add 32 lb, for a total of 183 lb of dry filter cake or sediment per ton of wire burned. The salvage value will depend on the content of copper and possibly other metals.

Based on the titrations of the scrubber water and impinger water, the burning insulation released to the furnace gases as chlorides a total of 187 lb of chlorine per ton of wire. Additional chlorine reacted with the copper and ash, becoming part of the product yield.

DISCUSSION OF RESULTS

Because the project was aimed primarily at reducing air polluton from wire burning, many other aspects of interest to metal salvagers were not investigated except incidentally. For example, it was soon obvious that a continuous furnace with steady feed and output would require less oil or no oil for practically complete combustion. A continuous furnace could be operated at lower excess air, thereby reducing the volume of flue gas to be cleaned.

The rate of burning of the batch furnace was low because air flowed through the wire layer by natural convection. Future investigations might include tests of controlled rates of air supply to the pan area. Production could also be increased by making the pan areas more nearly equal to the furnace plan area.

The effect of maintaining the gas temperatures at 1500 to 1550F was evident throughout the tests. Carbonaceous smoke of black or gray shade could be practically eliminated by maintaining sufficient temperature in the afterburner. The white smoke due to chloride fumes was not appreciably reduced by this means, although some benefit of high temperature was noted.

No test was conducted without the afterburner in operation. Carbonaceous smoke would have added to the scrubber load, resulting in an increased pollutant content of the scrubber exhaust. Furthermore, the additional hydrocarbons in the scrubber water would have greatly complicated the economical recovery of the hydroxides and the clarification of the scrubber water.

The period of emission and density of white smoke varied considerably with the type of wire. From experience with certain types of wire, one could predict in advance whether the evolution of white fume would be strong. The period of fuming was strongest while the wire burning was most active, and gradually declined as the wire and ash cooled in the furnace.

The gas scrubber performed most efficiently, 94.5 per cent, when the pressure drop through the agglomerator stage was highest, i.e. 37 inches of water column, or 1.335 lb per sq in. Collection efficiency is obtained at the expense of power at the exhaust fan and pump to obtain intimate contact and high relative motion of gas and water. The fine fume particles are not easily separated from the gases.

The water dissolved 85 per cent of the solids trapped by the scrubber. The final concentration of collected solids was under one per cent of the weight of the water, whereas the manufacturer reports that some scrubbers operate with the discharge water containing up to 7 per cent of solids.

In full-scale practice water is added continuously to the scrubber. The water consumption by the scrubber is due mainly to evaporation in cooling the flue gases, with only a small additional amount necessary to make up the overflow which removes the collected solids. The water consumption per ton of wire burned will depend on the initial temperature of the gases, amount of excess air and a few other factors, such as heat losses. These must be determined or estimated for each installation.

Likewise, the fan horsepower will vary with the quantity of flue gas produced, the saturation temperature of the scrubber exhaust, and the fan efficiency.

The data in Table V are of particular interest to those engaged in dust sampling. They emphasize the importance of careful washing of the sampling probe, thimble holder and tubing, as an important fraction of the dust may be deposited elsewhere than in the thimble filters.

The impingers following the thimbles also contributed significantly in trapping fumes which passed through the filters. The thimbles, probe and impingers trapped chlorides and minor amounts of carbon. No free HCl was found in the impinger water.

The dust loading of the flue gases was high, averaging 193 to 266 lb per ton of wire. The dust loadings in the scrubbed gases would have averaged 0.637 lb per 1000 lb of flue gas corrected to 50 per cent excess air if all flue gases had been scrubbed at 94.5 per cent collection efficiency as in the last Series. Cleaner gases are possible at greater expenditure for equipment and power. The results of these tests should be considered indicative and not final for commercial scrubbers.

The scrubber water from wire burning is acidic and hence corrosive to steel. However, scrubbers, pumps, fans and piping with plastic or ceramic linings are available to resist chlorides.

The scrubber water requires treatment before it could be discharged to streams. Neutralization with lime or other alkali causes the precipitation of most of the metals present by converting them to insoluble hydroxides. Filtration would clarify the water and permit recovery of the metal values, which are high in copper and zinc. The calcium chloride, a constituent of sea water, might not render the water objectionable for discharge into tidewater. The production of calcium chloride as a byproduct is a possibility. The method of disposal of scrubber water must be determined for each installation.

SUMMARY AND RECOMMENDATION

1. Nine tests were conducted on a commercial batch-type furnace for burning the insulation off copper wire. The purpose was to investigate the control of air pollution from the process.

2. The assorted insulated wire of 12 gage and under was burned on perforated pans with a total area of 120 sq ft. The charges averaged 1242 lb. The wire layers were 8 to 10 inches thick. The time from ignition to final cessation of fuming averaged 80 minutes.

3. The black smoke produced in the primary chamber was consumed by the oil-fired afterburner so long as temperatures of the gases leaving the afterburner were above 1500F. Under those conditions the stack emitted white fumes almost from the beginning of the burn, finally decreasing in density to a clear stack for 15 to 48 per cent of the total time.

4. Of the original weight of the wire, the average yield was 53.5 per cent No. 2 copper and 10.8 per cent copper-bearing ash. The weight loss to the flue gases was 35.7 per cent.

5. The dust and fume content of the raw stack gases averaged 240 lb per ton of original wire. The dust was 85 per cent water soluble, mainly metallic chlorides.

6. A continuous stream of the total flue gas was cleaned by water in a pilot-scale Peabody gas scrubber under three sets of conditions. At a total gas pressure drop of 42.7 inches water gage (1.54 lb/sq in) through the scrubber, a dust collection efficiency of 94.5 per cent was obtained. The scrubber water became black and acidic, but free hydrochloric acid was not found in the water.

7. By neutralization of the final scrubber water, the metallic chlorides were converted to hydroxides and precipitated at the rate of 151 lb per ton of wire. Per ton of wire an additional 32 lb of insoluble matter, present before neutralization, were also recovered by filtration. The proportionate amount of lime (CaO) required for neutralization was 69.7 lb, which left 138 lb of calcium chloride in solution in the clarified scrubber water.

8. The final dust content of the scrubbed flue gases was 0.675 lb per 1000 lb of flue gas corrected to 50 per cent excess air, or 0.36 grains per standard cu ft. Cleaner flue gas is possible, of course, at greater expenditure for scrubber equipment and power.

9. The investigation indicates possibilities for wire burning with low air pollution. The combination of a continuous burner with afterburning chamber and a gas scrubber of high efficiency warrants consideration. The recovery of byproducts, such as metal hydroxides and calcium chloride, may pay for much of the expense of gas cleaning.

ACKNOWLEDGMENT

The investigation and report were made possible by research grant RG-6760(C2) from the National Institutes of Health, Public Health Service.

The Michael Schiavone & Sons, Inc., of New Haven, Conn., cooperated fully in permitting the tests, and in supplying wire, fuel oil, power and labor as needed for the operation of the furnace. Peabody Engineering Corporation, New York, N. Y., lent a pilot gas scrubber and auxiliary equipment.

The authors also appreciated the interest of numerous persons and companies who provided experience and technical background.

REFERENCES

1. Private communications, numerous sources.

2. Private communication from Phelps Dodge Copper Products Corp.

3. Coleman, E. H. and Thomas, C. H. The products of combustion of chlorinated plastics. Jl. Applied Chem., Vol. 4, pp. 379-383, 1954.

4. Siegle, J. C. and Muus, L. T. Pyrolysis of polytetrafluoroethylene. Presented to American Chemical Society, Sept. 17, 1956.

5. Spitz, Albert W. New Way to Burn Scrap Copper Wire. Air Engineering, pp 24,50, July 1959.

6. Kaiser, E. R. and Tolciss, J. Smokeless Burning of Automobile Bodies. Jl. Air Pollution Control Assn., Vol. 12, pp 64-73, 1962.

7. Kaiser, E. R., Halitsky, J., Jacobs, M. B., and McCabe, L. C. Modifications to Reduce Emissions from a Flue-Fed Incinerator. Jl. Air Pollution Control Assn., Vol. 10, pp 183-197, 207, 251, 1960.

8. Wiest, G. J. Lime as a Neutralizing Agent. Ind. Water & Wastes, Vol. 7, No. 1, pp 14-16, Jan. - Feb. 1962.